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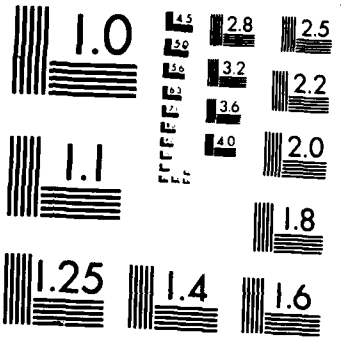

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This grant, AFOSR-81-0109, "Three Dimensional Laminar Boundary Layers" extended from March 1, 1981 to December 31, 1984. It was a continuation of earlier contracts, F4462-70-C-0085 and F49620-76-C-0004, devoted to the subject of laminar flows in three dimensions. During this grant period, efforts were first focused on settling the fundamental question of three-dimensional separation. New evidences continue to lend support to our open separation concept. Later emphasis was shifted to the preparation of a monograph to bring together the newly developed materials on the subject of three-dimensional laminar flows into

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FINAL SCIENTIFIC REPORT

ON

THREE-DIMENSIONAL LAMINAR BOUNDARY LAYERS

to

Director of Aerospace Sciences
Air Force Office of Scientific Research (AFSC)
United States Air Force
Under Grant No. AFOSR-81-0109

Principal Investigator: K. C. Wang

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and Engineering Mechanics
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San Diego, CA 92182-0183

SUMMARY

This grant, AFOSR-81-0109, "Three-Dimensional Laminar Boundary Layers" extended from March 1, 1981 to December 31, 1984. It was a continuation of earlier contracts, F4462-70-C-0085 and F49620-76-C-0004, devoted to the subject of laminar flows in three dimensions. During this grant period, efforts were first focused on settling the fundamental question of three-dimensional separation. New evidences continue to lend support to our open separation concept. Later emphasis was shifted to the preparation of a monograph to bring together the newly developed materials on the subject of three-dimensional laminar flows into a unified treatment.

I. Problem

The question of three-dimensional separation is a complicated one; it confuses experts let alone ordinary readers. Standard texts (e.g. Schlichting's) have little to say about this subject and what they did mention has been by now proved to be mistaken. The open-VS-closed separation idea which we introduced about a decade ago offers an entire new understanding of this problem. This idea has been consistently supported by computations and experiments, but there were still misleading criticisms which cause confusion in the research literature.

During this grant's early periods, we searched to answer those criticisms and to pinpoint where the opposing arguments are flawed. Tobak and Peake (Paper AIAA-79-1481) repeatedly attempted to contradict the open separation idea, when they finally (paper AIAA-81-1260) found that they had to accept the open separation idea, they chose to speak instead in terms of a different terminology. Cebeci, Khattab and Stewartson (JFM, 107, 1981) repeated our calculations and found almost identical results. They admitted open separation being a real phenomenon in real flows, but questioned the procedure of legitimacy because boundary layer theory cannot determine the flow on the leeside of the separation line. Instead, justification of the open separation has to rely in part on evidence from experiments. To counter their objection, we pointed out that an example of calculating the flow on both sides of an open separation line (VS using partly experimental evidence) has become available by the thin layer approximation. Secondly, we consider the legitimacy question is peripheral so long as the concept is correct. More recent experiments by Bippes and Turk (DFVLR Gottingen IB222-83 A 07) provide further support to the idea of open separation. The open separation structure is much more clearly demonstrated than ever before, and an open separation may even occur within a closed separation. These are discussed in details in the forthcoming monograph.

During the remaining grant period (summer, 1983-1984), efforts have been focused on the preparation of a monograph tentatively entitled "Three-Dimensional Laminar Flow Theory". It is intended to bring together the new material developed in the past 15 years in the area of three-dimensional laminar flows into a unified account. Boundary layer theory represents the basic theme; other approaches involving inviscid-visicous interactions (i.e. the thin layer approximation) are also included. Theories and experiments are evenly weighed, physical understanding takes priority over any other considerations. The separation phenomenon is emphasized throughout. The progress of this project has not been as fast as originally expected. At the time of this writing, three-quarters of the whole project have been finished.

II Achievements

Papers and Reports:

1. "New Development in Open Separation," in Three-Dimensional Turbulent Boundary Layers, editors Fernholz and Krause, Springer-Verlag, New York, 1982.

2. "On the Disputes About Open Separation," AIAA paper 83-0296, 1983.

3. "Separation Jump and Sudden Stall", AIAA Journal, vol. 22, No. 9, September, 1984.

4. "New Developments About Open Separation," Report AE & EM TR-82-02, San Diego State University, July, 1982. Also AFOSR-TR-83-0739, 1983.

Monograph:

Nine Chapters have been written, 6 of them have also been edited:

1. Introduction

2. Basic Equations

3. Characteristic Study of Equations

4. Separations

5. Numerical Methods

6. Symmetry-Plane Boundary Layer

7. Blunt-Body, I. Spheroid

8. Blunt Body: II Cones & Hemisphere-Cylinders

9. Flow With Rotation

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